THE COURSE IN NATURAL SCIENCE IN THE UNIVERSITY ELEMENTARY SCHOOL. III

Prepared by

OTIS W. CALDWELL
C. FRANK PHIPPS
MARGARET M. GORDON
ADALINE SHERMAN
CORDELIA KINGMAN
GRACE E. STORM
TIRZAH S. MORSE
ELEANOR TROXELL
ELSIE A. WYGANT

GRADE VI

In the first semester personal and community hygiene receives the major amount of attention. As a preliminary to this study, the pupils treat in an experimental way several questions about the struggle for existence in the plant and animal kingdoms. A brief treatment of man's struggle for existence follows. The pupils learn that more plants and animals begin life than can possibly mature and that there are various factors which limit life. This serves as an introduction to the study of personal hygiene. The pupils learn that their bodies are like machines, which must be treated properly to function efficiently. In the study of community hygiene they become interested in milk and water supply, garbage and sewage disposal, the sanitary preparation and distribution of food, prevention of the spread of infectious disease, and parks and playgrounds.

In the second semester the subject is magnetism and electricity. The pupils make much of the apparatus used and perform their own experiments with it. Along with the experimentation they make and use magnets; construct and use push buttons, cells, burglar alarms, and galvanoscopes; do simple wiring; study electric bells, buzzers, compasses, and electroscopes and telegraph instruments; and examine the telephone and the wireless apparatus.

Children of this age are keenly interested in learning to manipulate apparatus and to experiment with some of the forces of nature,

and in understanding some of the practical applications of these forces in the industries.

OUTLINE OF MATERIALS AND ACTIVITIES

A. Struggle for existence among plants
  1. Using several of the following: sunflower, cress, radish, hollyhock, butterprint
    a) Pupils collect plants with seeds from gardens and vacant lots.
    b) They sketch the seed-bearing structure and seeds.
    c) They count seeds of single plants and compare numbers. They count single seeds, or pods, or by spoonfuls, or by weighing and computing.
  2. Pupils estimate ground needed if all the seeds of the plants brought in should grow.
  3. What are some of the factors which limit the growth of all the seeds which mature and are scattered broadcast and how do these factors operate?

B. Factors concerned in the growth and welfare of animals and man
  1. The problem of getting food
    a) Methods adopted by animals to secure food. Use of teeth, claws, sense of smell, etc.
    b) How does man secure his food? Primitive man and man of today. Pupils trace food from farm, ranch, etc., to city markets and homes.
  2. The teeth: kinds and uses
    a) The teeth of certain animals, such as cat, beaver, horse; adaptations for purposes served.
    b) Man's teeth are compared with those of animals.
      (1) Resemblances and differences.
      (2) The first set, or milk teeth.
      (3) The second set, or permanent teeth.
      (4) Function of teeth.
      (5) Pupils study their own teeth at home with mirror and count number of each kind.
    c) Care of the teeth.
      (1) When they should be cleaned.
      (2) How they should be cleaned.
      (3) Decayed and crooked teeth.
      (4) Why periodical visits to the dentist are necessary.
  3. Mastication and digestion of food
    a) Reasons for chewing food.
    b) Saliva and salivary glands.
    c) Drinking water at meals.
    d) Rapid eating and overeating.
    e) Irregular hours for meals and eating between meals.

f) Candy and other sweets.
g) How is digested food sent to all parts of the body?
h) How does food help to heat the body and nourish it?

4. Stimulants and narcotics

Meaning of stimulant. Dangers in the use of stimulants. Tea and coffee. Alcoholic drinks. Tobacco. Cigarettes.

5. The blood

Circulation of the blood. Counting the pulse while sitting and after exercise. Why beat faster? Relation to heart beat.

6. Ventilation

Relation of fresh air to the blood. Relation of CO_2 to ventilation. Pupils experiment with CO_2 from the lungs, testing it by blowing through tube into limewater. Demonstration by groups of children with a box having sliding glass cover and holes on sides for windows. Candles are burned inside to represent people. (In what ways are candles like people?) Best methods of ventilating the house and especially the sleeping-room. Ventilation system of our school.

7. Respiration

a) Parts of the body used in breathing.
b) Deep and shallow breathing.

C. Personal hygiene

Teacher puts a sentence, or "health epigram," on the board daily, concerning the hygiene of the body, the home, the city, etc. It serves as a text for a short discussion in which teacher and pupils share.

1. The living machine

The body is compared to the steam engine. How can we get the most and best work out of each?

2. Hearing and eyesight

The structure of the ear is demonstrated by the use of a model. Use of wax in the ears. Care of the ears. The structure of the eye is demonstrated by the use of a model. How best use the eyes in reading. Good and bad reading lights. Care of the eyes.

3. Sleep

Why do we need sleep? The body is compared to the electrical storage cell. Hours for sleep needed by children.

4. Personal cleanliness

Necessity for keeping the body clean. Bathing and cold showers. Public baths, bathing suits, and towels. When not to bathe.

5. Colds

How we take cold. How to avoid colds.

6. Athletics, exercise, and outdoor life

Value of physical exercise. Danger of strenuous sports.

7. First aid to the injured

Fainting. Nosebleed. Bleeding from cuts. Burns. Burning clothing. Bee stings. Drowning and other accidents.

D. Hygiene and city life

1. Means used by the city to keep the people healthy

Playgrounds, parks, and public baths. Street cleaning. Ashes and garbage. Inspection of foods. Health regulations.

2. Water supply

Methods employed for purifying drinking water. Wells and springs.

3. Sanitary conditions of stores

Pupils select one or more stores in their communities, visit, and report on their condition.

4. Contagious diseases and their control

Causes of certain infectious diseases. Some common diseases and treatment of patients. Mosquitoes, malaria, and yellow fever. Flies as spreaders of disease. Pets as spreaders of disease.

5. Healthful homes

Importance of sunshine and fresh air in the home. Objections to carpets, heavy upholstery, draperies, etc. Ventilation in the home (a review). Outdoor sleeping-rooms. Sweeping and dusting. Care of the sick room. Importance of the family's investigating milk and water supply, markets, groceries, etc.

E. Magnetism and electricity

1. Bar magnets

Pupils experiment with various kind of magnets and determine their properties and their differences. Study lodestone. The compass.

2. The electric bell or buzzer

These are studied by the pupils, the parts learned, and the differences between them noted. Pupils attach bell to dry cell and learn why it rings and how it rings. Pupils trace the path of the electric current through the bell. Diagrams of bell are drawn in notebooks and parts labeled. Applications: doorbells, school bells, call bells, etc.

3. The cell (grenet or bichromate)

Pupils make a cell in a bottle with potassium bichromate, water, and sulphuric acid, carbon and zinc rods. Connect it with bell and use it.

4. Push buttons

Pupils study the common type and connect button with bell and cell. When the principle is learned the pupils make a simple push button with a block and two pieces of metal and connect it with cell and bell. Applications.

5. Burglar alarm

Pupils bring boxes with sliding wooden covers and devise ways of attaching metal strips or wires to the box or cover (which represents a

window) and connecting with a bell and a cell so that the bell rings when the cover is raised.

6. Wiring houses for doorbells and call bells

   Pupils draw diagrams applying the principles already learned to wiring a house for a front-door bell, and a call bell in kitchen connected with the dining-room table. Several drawings put on board for class criticism.

7. Other kinds of cells

   The dry cell. Pupils examine an old cell and learn how it is made. Diagrams are drawn. Discussion of why cells wear out and how they may be revived. Voltaic cells are made by pupils and used with bells and galvanoscope.

8. The galvanoscope

   Pupils are given the idea that a wire must be wound around a block in such a way that a compass can readily be slipped under the wire. Then they devise the best way.

   The galvanoscope is connected to cell and push button, placing the block so that the wire runs parallel with the compass needle. Pupils note and try to explain the action of the needle when the current is turned on. The effect on the needle is noted when more or less wire is wound around the block, and when more or less current is used. Applications: to test a cell for a current; to learn something of the strength of the current.

9. Frictional electricity experiments

   Static or frictional electricity. Studied by experiments with glass rods, ebonite, flannel and silk, cork, etc. Discussion and illustrations of the electroscope, the electrophorus, and the nature of lightning.

10. Electric currents used for heating

   Pupils connect two dry cells with very short piece of small iron wire. Why does it become red hot? Application to electric lights, heating cars, cooking by electricity, electric irons, etc.

11. The solenoid

   Pupils make solenoid by winding covered copper wire around a pencil, then removing pencil. They attach it to a cell and push button and test ends of the coil of wire with compass and iron filings. Results and causes.

12. The electromagnet

   Pupils put a nail through the solenoid and test nail with iron filings. Test each end with compass. They bend a large nail, or bundle of iron wires, into U-shape and wind with covered copper wire, and test. Use of electromagnets in bells, buzzers, telegraph instruments, mining, and other industrial operations.

13. The telegraph instrument

   Pupils make a simple instrument by using the U-shaped magnets on a block of wood. Simply made push buttons are used for keys.

They connect instruments and send messages, using the Morse or the Continental code.

14. The telephone

    Pupils study receiver and transmitter and learn how they work and how conversation is transmitted.

15. Electric lamps

    The carbon lamp, tungsten or mazda, and the arc light are examined, studied, and drawn.

16. Electroplating

    Pupils put some copper sulphate solution in a tumbler with a copper strip and something to be plated. They attach wires from a cell to the copper and to the thing to be plated, and turn on current. They remove the plate by reversing the current. Discussion of silver-, gold-, and nickel-plating.

17. Electric motors and dynamos

    Pupils test and study toy motors. Teacher demonstrates how electricity is made with hand-power dynamo. Uses of motors and dynamos. A power plant is visited by the class.

18. Trolley cars

    By diagrams on the board the class is shown how motors are used in running cars. Third-rail system explained.

19. Wireless telegraphy

    Demonstration: sending and receiving apparatus is set up in the room with overhead wires and operated by the pupils.

TYPE LESSONS

The type lessons here presented will serve for both sixth and seventh grades.

A. Bar magnets

1. Pupils experiment and make lists of things attracted and not attracted.
2. Pupils suspend magnet to see where it points.
3. Lodestones or natural magnets.
4. Pupils determine by experiments how the poles of magnets behave toward each other.
5. Pupils learn to make magnets out of pieces of steel or watch springs.
6. Other metals are tried to see if magnets can be made from them.
7. Pupils reverse poles of each watch-spring magnet.
8. Pupils heat a watch-spring magnet to take magnetism out.
9. Watch-spring magnets are broken in halves to see if they are spoiled.
10. Action of a magnet on a compass.
11. Pupils experiment with magnet, nail, and iron filings to learn about magnetizing by conduction and induction.
12. Dipping compass needles, and how they work.

13. Earth's magnetic poles and magnetic field about the earth. Relation to compass.
14. Pupils determine what substances magnetism will act through by placing iron filings on paper, cardboard, board, sheet metals, etc., and rubbing the magnet under each.
15. Pupils study magnetic field about a magnet by laying cardboard over a magnet, sprinkling iron filings on the cardboard, and gently tapping it. Different combinations of two or three magnets are tried.
16. Pupils explore the field about a magnet with a compass.
17. The compass is studied and a simple one is made.

B. Static or frictional electricity

1. Pupils are given glass rods and ebonite rods, pieces of flannel and silk, cork, pith, and some bits of paper.
   a) They rub the ebonite with the flannel or on their clothing, and bring it near the bits of paper. (A rubber comb, a stick of sealing wax, and a fountain pen are also rubbed and tested.)

   How do the bits of paper act?

   Hold the hand near the rod with papers on it. Does the paper fly to the hand? Does it jump back to the rod?

   What reason can you give for the behavior of the paper?

   Place your hand on the rubber part of the rod, then try it with the paper again. Do the bits of paper stick to the rod now? Why?

   b) Rub the glass rod with silk and repeat the experiments.
2. The pupils suspend by a silk thread a small piece of pith (from corn, elder, or burdock) or a piece of cork or small paper wad and bring the rubbed rod near it.

   What happens first?

   Why does the pith jump away from the rod?

   Can you now catch it or touch it with the rod?

   Touch the pith with the fingers and try again. Why is it again attracted to the rod?

   The questions bring out the fact that the pith is first attracted to the charged rod, becomes charged with the same kind of electricity as the rubbed rod has, and then flies away because like charges repel each other.

   How does this action compare with the action of poles of magnets?
3. Next the pupils charge the pith again with the ebonite rod and then bring near the pith the rubbed glass rod.

   Why does the pith, charged by the ebonite rod and repelled by it, now become attracted to the glass rod?

   Are the electric charges on the different rods alike or different to do this?
4. Rub an ebonite rod and suspend it so that it swings easily.

   Bring another rubbed ebonite rod near it.

Bring a rubbed glass rod near the suspended rod.

In each case how does the suspended rod behave?

What rule can you make regarding the action of like charges and unlike charges on each other?

C. The electroscope

1. Pupils make a "bottle detector" or electroscope (see reference books) and test and charge it with rubbed rods.
2. Pupils send an electric charge through a wire which is attached to the wire in the bottle, by touching the rod to the loose end of the wire. (Static electricity changed to current electricity.)

D. The electrophorus

Pupils make by mixing and melting 3 oz. resin, 1 oz. dry shellac, and 1 oz. beeswax in a tin pie plate and allowing to cool. To a smaller pie plate they attach some silk threads to hold it by.

Experiments are performed with it by the pupils further to illustrate static charges.

E. Lighting

The storage of electricity in clouds, the passing of charges (lightning flashes) between two clouds or between a cloud and the earth are shown to be phases of natural static electricity.

Thunder, lightning rods, and sheet lightning are discussed.

F. Other ways of producing static electricity

Many children are familiar with examples of making it, such as stroking a cat's back, scuffing on a carpet, combing the hair on a cold morning, etc.

Time allotment.—Two hours per week are allotted to this course in the sixth grade. No assignments for home study are given. More than half of the class time is used for experimentation and construction; the rest is used for discussion, writing records and drawing, and supervised study.

Textbook.—For the course in hygiene, two textbooks are used: O'Shea and Kellogg, *Health Habits*, and Jewett, *Town and City*. Other books are used freely for reference and supplementary reading.

No textbook is used in the course in magnetism and electricity. A notebook is kept by each pupil in which he records his experiments and the principles learned.

References for the teacher.—

1. Hygiene

O'Shea and Kellogg, *Health and Cleanliness*.

Bertha Brown, *Health in Home and Town; Good Habits for Boys and Girls*.

C. N. Millard, *The Wonderful House That Jack Built.*
A. P. Knight, *Hygiene for Young People.*
Woods Hutchinson, "Woods Hutchinson Health Series."
Hoag, *Health Studies.*

2. Magnetism and electricity
   Avery-Sinnot, *First Lessons in Physical Science for Grammar Grades.*
   Harrington, *Physics for Grammar Schools.*
   Higgins, *Lessons in Physics.*
   Various high-school textbooks in physics.

GRADE VII

This course consists largely of laboratory work in elementary physics. The aim is to give information about ways in which physical forces are used in the arts, to foster the desire to investigate, to stimulate more scientific thinking, and to develop constructive ability. The list of projects shown below includes work with glass tubing, such as cutting, bending, sealing, and drawing; the making of fountain-pen fillers and apparatus for use in experiments in boiling, distillation, siphoning, etc.; the making of air thermometers; the constructing of levers and other simple machines; experimentation with solutions and crystallization; the making of coal gas; and devising apparatus for filtering water.

OUTLINE OF MATERIALS AND ACTIVITIES

A. Some effects of heat
   1. Boiling water
      a) Pupils boil water in glass flasks and note the many phenomena.
      b) They find temperature of boiling water.
      c) They find temperature of steam.
      d) They compare temperatures of boiling water and boiling alcohol.
      e) Effect on boiling temperature of adding salt, etc.
      f) Under certain conditions water will boil at lower temperatures.
      g) Application of this principle to cooking at high altitudes.
   2. Evaporation
      a) Experiments on evaporation. Discussion.
      b) Pupils set some water aside and heat for a few minutes an equal amount to see if evaporation can be made to occur more rapidly.
      c) Pupils use vessels of different shapes to see in which evaporation occurs the fastest.
      d) They learn by experiment that evaporation results in cooling.
      e) Application of principle.

3. Condensation and distillation
   a) Pupils try experiments to condense steam.
   b) The pupils devise and make apparatus for condensing steam faster and use this for separating water from different solutions.
4. Some effects of application of heat to solids, liquids, and gases
   a) Solids

      Pupils heat iron wire and other metallic substances and learn that they expand

      Applications to bridge-building, riveting, railroad tracks, etc.
   b) Liquids

      Pupils heat a flask of water, having a glass tube in the cork, and find that the water expands. On cooling, it contracts again.

      Discussion of freezing of ponds; floating of ice; bursting of frozen water pipes, mercury thermometers, etc.
   c) Gases

      Pupils learn by keeping the glass tube in the stopper of a flask under water, while holding the flask in the warm hands, that air expands when heated. Why is water "sucked up" into the tube when the hands are removed?

      Application to drafts and chimneys, hot-air furnaces, hot-air balloons, etc.
5. Conduction of heat
   a) Pupils learn something about conducting power of wood, iron, copper, and aluminum wire, etc., by holding one end of each in the flame.

      Do all metals conduct heat equally well?

      Why does a tiled floor feel colder than a rug in the same room? An iron or stone object colder than wood, rubber, etc.?
   b) They test the conducting power of water by heating the top of a test tube of it to boiling while holding it at the bottom.

      Why does water in a room feel colder than the air of the room which is of the same temperature?

      Poor conductors of heat: covers of steam pipes, wooden handles on kitchen utensils, asbestos mats, double-doors and windows, woolen clothing, thermos bottles, etc.
6. Heating buildings by hot water and warm air
   a) Pupils heat gently a test tube of water containing a little sawdust, noting how the sawdust acts.
   b) Demonstration of hot-water heating with chalk boxes made to represent rooms and glass tubing for pipes, connected with tank on top. Heating the lower part of pipe causes the water to circulate.
   c) How do currents of air move in a room where there is a hot stove? Simple experiments are performed to show convection currents of air.

7. How can we prove that the sun, a flame, a hot stove, or a fireplace radiates heat?

   Pupils devise and perform experiments.

8. The meaning of burning
   a) Pupils ignite a match or splinter. Why does it burn?
   b) Burn a stick with a hot rod of glass or iron.
   c) Ignite sulphur and phosphorus with warm rod.
   d) Is air necessary to burning? How can we prove it?
   e) Separate nitrogen from the air and test it with burning stick.
   f) Pupils make several bottles of oxygen and test it.
   g) Kindling temperature. Meaning.
   h) Rusting and combustion. Cause and prevention of rusting.
   i) Spontaneous combustion. Demonstration.
   j) Lessons from a burning candle.
   k) How to put out small fires.
9. Heat and cold by other chemical action
   a) Pupils learn that heat is produced by putting sulphuric acid into water or by putting an acid on zinc.
   b) Pupils take temperature of a dish of water and then dissolve salt in it. Is temperature the same? Repeat, using sal ammoniac, ammonium chloride, and ammonium nitrate.
   c) They mix salt with cracked ice and take temperature. How does a mixture like this freeze ice cream?
10. Thermometers
    a) Types of thermometers are studied.
    b) Pupils make an air thermometer and compare its workings with a standard thermometer.

B. Work with glass tubing
   1. Pupils learn how to cut or break glass tubing, how to bend it after heating it, how to seal it, how to draw it out, and finally how to make fountain-pen fillers. This gives the class ability to make new kinds of apparatus.

C. Study of simple machines
   1. The teeter-totter or seesaw
      a) With sticks, fulcrums, and weights the pupils solve simple problems and learn the relations between the lengths of the parts of the seesaw on each side of the fulcrum and the weights.

         By using the same stick as a crowbar the power necessary to pry up or lift a given weight is easily solved. Such topics as this are correlated with mathematics.
      b) The following machines are studied and classified: scissors, balance scale, pincers, pump-handle, wheelbarrow, nutcracker.
      c) Pupils make balance scales of blocks, sticks, and cardboard and weigh things and study principle.

2. Other machines
   a) Another type of machine, represented by the windlass and water bucket, is demonstrated and the relation between the weight of the bucket of water and the muscular power necessary to draw it up is studied.
   b) The principle of the derrick is illustrated in the same way. Practical mathematical problems are solved.

      Applications of this type of machine: drawing well-water; derricks; railroad hand-cars; capstan or windlass on ships; moving buildings by horse-power, etc.
3. The skid or plank used by teamsters in loading wagons
   a) Groups of pupils demonstrate by using a board 3 or 4 feet long. If this is inclined and a toy cart is loaded and rolled up, or pulled up by spring balance, the relation between the length and height of the skid, the weight of the load, and the power needed to push it up are learned.

      Applications: loading wagons and cars; coal and ore cars pulled out of mines; wagons drawn up hills; gang planks in loading steamers, etc.
4. The pulley—another type of machine
   a) Pupils in groups experiment with pulleys and learn the advantages and disadvantages of each kind or combination of kinds.

      Problems are given to solve with pulleys, using the principles learned.

      Applications: hoisting heavy objects; raising sails on ships; moving buildings; clotheslines; derricks; dredges; wrecking-trains, etc.
5. Steam engines
   a) Teacher demonstrates the power of a small amount of steam by boiling a little water in a corked test tube.
   b) Steam power applied to running an engine. A toy engine is run to demonstrate its working, and pupils draw it and learn parts and principles.
6. Discussion of machines; advantages and disadvantages; types which sacrifice power in exchange for speed or vice versa, etc.

D. Friction
1. Effects of friction
   a) Pupils do simple experiments showing that friction causes heat. Other effects—wearing of parts, hard to move, squeaking hinges, hot boxes on trains, etc.
   b) Ways of lessening friction.
   c) Advantages and disadvantages of friction.

E. Pendulums

1. What is a pendulum?

   a) Groups of pupils demonstrate, by using pendulums of different lengths, the relation between the length of pendulum and number of swings; the length of the swing of a pendulum and the number of swings; the use of different substances for bobs; the length a pendulum must be to vibrate once a second.

   How may a pendulum clock be regulated so as to go faster or slower?

   Applications and history of the pendulum.

F. Some simple lessons on matter

1. Definition of matter

   a) Pupils try to pour water through a funnel-tube in the stopper of an air-tight bottle.

   b) They displace air from one bottle by pouring in water through a funnel-tube and collecting this air in another bottle over water.

   c) They push an inverted tumbler down into water and note whether water enters the tumbler.

   d) Does air take up space? Is it matter?

   e) They drop a stone into a glass even full of water.

   f) Do water and stones take up space? Are they matter?

   g) Definitions (drawn from the pupils). Matter is anything which occupies space. No two things can occupy the same space at the same time.

2. Solids, liquids, gases

   a) Pupils name and classify different forms of matter about them.

   b) Pupils learn the difference between solids, liquids, and gases by noting some of their different characteristics.

3. Some changes in matter—physical and chemical.

   a) Pupils dissolve some salt in water, and heat a few drops of the clear water in a spoon or dish. Can the salt be regained? Where was it when dissolved?

   b) They dissolve zinc in acid and evaporate a few drops. Is zinc regained?

   c. The change in (*a*) is called physical; in (*b*) chemical.

   Applications: Explain each kind of change in melting ice; burning stick; freezing water; rusting iron; souring milk; breaking stick; burning a building; digesting food; etc.

4. How crystals are made

   a) Pupils dissolve alum and potassium bichromate in hot water in separate dishes and suspend a string or wire in each solution for a few hours until crystals form. Examine them.

b) How does ice look when first forming?
c) Formation of crystals in nature in rocks and minerals.

Application of crystal forming: making rock candy; separating pure substances from impure; making medicines and chemicals.

5. The force that holds matter to the earth
   a) Pupils do simple experiments to illustrate the effect of gravity.
   b) Can gravity be measured? Pupils learn that it can be by weighing things.
   c) Where is the center of gravity of a body, the point at which it may be balanced? Pupils find this point in an irregular piece of cardboard.
   d) Pupils learn by simple experiments the relation between this center of gravity and the stability of a body.

   Applications: To walking; load of hay and load of stones; comparative ease in tipping over; ink bottle with large base, etc.

G. A study of the atmosphere
1. What is atmosphere?
   a) Pupils learn by experiments that the air has resistance, and that this is a factor in birds' flying and the flying of airships.
   b) Other experiments show that air can be compressed and resists compression, and the principle is used in many ways.
   c) The elasticity of air is learned by the use of the popgun, bicycle pump, air gun, balloon, football, air cushion, etc.
   d) Another series of experiments illustrates the pressure of air, and applications are made to the drinking of lemonade through a straw, to barometers, to pumps, to siphons, to breathing, etc.
   e) The barometer and its relation to the weather, pumps and how they work, and siphons are studied by means of simple apparatus.
2. Oxygen and nitrogen, which were studied under combustion or burning, are reviewed
   a) Carbon dioxide, another gas of the atmosphere. Pupils make it by putting acid on marble, collect it and experiment with it to show its effects on a flame and on limewater.
   b) The carbon dioxide from the lungs is shown by breathing or blowing into lime water.

   Applications of CO_2: plant life; refrigeration; fire extinguishers; bread-making; liquors; ventilation.

H. The making of other gases
1. Coal gas
   a) Pupils fill the bowl of a clay pipe with soft coal, seal it up with plaster of Paris and heat it. The gas given off is lighted.
   b) By-products obtained in making coal gas: ammonia, coal tar, and coke. (Ammonia is not detected in this experiment.)

2. Gas from wood
   a) Pupils seal up chips or shavings in a clay pipe as in (*a*) and heat. Gas given off is lighted.
   b) By-products: charcoal, an acid (tested with blue litmus paper), and a tarry substance. From the last wood alcohol is made commercially.

I. Some lessons about water
1. Water pressure
   a) By easy experiments with home-made apparatus pupils learn that pressure increases with the depth of the water.

      Application to deep diving and its effect on the ear drum.
   b) The fact that water has a pressure in all directions and that this pressure is equal in all directions is simply demonstrated.
   c) Water maintaining a level is shown by connecting lamp chimneys or glass tubes with rubber tubes, pouring water into one of them and noting effect.

      Application to water gauges on boilers, coffee and milk urns, city water supply from reservoirs and artesian wells.
2. Buoyancy of water
   a) Pupils put several floating bodies in water and infer causes of floating, with the help of questions.

      Does the same principle apply to balloons in air?
   b) Pupils determine whether water pushes up on stones or other heavy objects by weighing in the air and again when suspended in water.
   c) Name of this upward push of water—buoyancy.

      Application: a bucket of water when in the water in the well and when lifted out; a heavy stone lifted under water; ships floating; swimming, etc.
3. What determines how far down in water a stick, a piece of soap, a cork, or paraffin will sink?
   a) Pupils weigh a stick, let it float in a graduated tube, taking the reading of the level of the water before and after the stick is put in. They learn from class discussion that the stick sinks until it pushes aside an amount of water equal to its own weight.

      How much water is displaced by a swimmer floating?

      Why does a fresh egg sink in plain water and float in salt water?

      Why do iron ships float? Experiments and principles learned in (*a*) explain it.

      Will a ship displace a greater or less volume of salt water than fresh water? In which will it sink the deeper?

J. Lessons in sound
1. Cause and nature of sound—vibration.
   a) Pupils sound a tuning fork and hold a suspended pith ball against it.
   b) They strike a bell or gong and hold a suspended pith ball against it.

c) They touch a vibrating tuning fork to the rim of a glass.
d) They touch the surface of water with vibrating fork.
e) They place a dish of water on edge of table and rap other end of table. Result? Cause?
f) They place fingers on throat and speak loudly. Do the vocal cords seem to vibrate?
g) Discussion on how vibrating bodies cause the sensation of hearing.

2. Transmission of sound
   a) Teacher suspends a toy bell on a wire in a corked flask. Sound it. Put water in, boil it, cork up while steam is coming out. When steam inside is condensed sound bell again. Can it be heard?
   b) Pupils place ear at end of a long stick, log, or iron bar and have some one scratch other end with a nail or pin. Can the scratching be heard?
   c) Sound in water. When in bathing and under water strike two stones together. Is the sound louder than in air?
   d) Sound, then, is transmitted by a wave motion of matter, such as a gas, a liquid, or a solid.
   Discussion as to how waves are sent out or propagated.
   e) Simple telephone, made with tin cans and string, illustrates wave motion.
   f) Wave motion in iron shown by placing ear on railroad track while the track is struck a good distance away.
   g) Velocity of sound as compared to the velocity of light.
3. Echoes—their cause
4. Speech and the phonograph. Simple explanation
5. Pitch. Nature of pitch
   a) Pupils illustrate by tying string to desk and pulling tighter while plucking it.
   b) They shorten or lengthen the string and pluck it. Results?
   c) They try different sized strings but of same length. Does pitch vary with length, tension, and size of string?
   Application: violins and other stringed instruments.

K. Lessons on light
1. What is light?
   a) How do we see objects? Discussion with simple explanations.
   b) Pupils find the direction in which light waves or rays travel by making holes in three pieces of cardboard and standing the cardboards in a row so that the light from a candle shines through all the holes. Are the holes in a straight line?
   c) Do waves or rays of light travel in straight lines when entering or leaving water? A coin is put in a dish of water and pupils stand just

far enough away so that the coin cannot be seen over the edge of the dish. Why does the coin appear to view when water is poured into the dish?

d) Fish in ponds appear nearer the surface than they really are. Why?

e) An oar or pencil in water appears bent or broken. Why?

f) Transparent, translucent, and opaque bodies are defined.

2. Lenses

   a) Pupils try a burning glass in the sunlight. What causes it to burn? Of what shape is it?

   b) They try a concave lens. Why is the effect different?

   c) Lenses in cameras, opera glasses, our eyes, are briefly explained.

   d) Photography.

      (1) Pinhole camera. If there is time pupils make cameras and take pictures.

      (2) Lens camera. How pictures are taken, developed, and printed.

3. Color. Why an object is red, green, etc., is simply explained.

4. The rainbow. When can it be seen? What causes it?

Time allotment.—Two sixty-minute periods per week are given to this work throughout the year. The major part of the time is used for experimentation and construction, and the rest for discussion, reference reading, and the preparation of records for the notebooks. The pupils do considerable optional after-school or home work in connection with the experimentation.

Textbooks.—No textbook is used, but pupils are referred to library books and to periodicals for information on many of the topics.

References, mainly for teachers' use.—

Avery-Sinnot, *First Lessons in Physical Science for Grammar Grades.*

Higgins, *First Science Book; Lessons in Physics.*

Harrington, *Physics for Grammar Schools.*

Holden, *The Sciences.*

Bertha Clark, *General Science.*

Rowell, *Elementary General Science*, Book I.

Hessler, *The First Year of Science.*

Woodhull, *Home-made Apparatus.*

Magazines: *Popular Mechanics*, *Popular Electricity*, *Popular Science Monthly*, *What to Do*, *American Boy*, *Scientific American.*

Many high-school textbooks in physics and chemistry.